The Environmental Impacts of BART

Interim Service Findings

Interpretive Summary

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a report by the Metropolitan Transportation Commission

Hotel Claremont, Berkeley, California 94705

The Metropolitan Transportation Commission was established by the California Legislature in 1970. Its 19 members represent city and county governments, and federal, state and regional agencies that deal with transportation and urban development.

MTC's duties include: planning regional transportation in the nine counties surrounding San Francisco Bay; reviewing applications for federal funds for transportation improvements that have regional significance; and allocating state funds for mass-transportation projects.

As part of its transportation-planning effort, MTC undertook the study of BART that is described in this report. The report is distributed under the sponsorship of the U.S. Department of Transportation and Department of Housing and Urban Development, in the interest of information exchange. The United States Government and the Metropolitan Transportation Commission assume no liability for its content, or for the use thereof.

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BART — the Bay Area Rapid Transit system — is a commuter-oriented rail rapid-transit system that serves three counties on San Francisco Bay.

BART began operating in September 1972; by late 1975, it was handling about 120,000 one-way trips a day on weekdays. Planned expansion of service is expected to increase weekday patronage to 200,000 trips a day.

In 1972, the Metropolitan Transportation Commission began a study of BART's impact on the people, the communities and the region that it serves. A major element in this BART Impact Program is the Environment Project, which seeks to analyze BART's effects on the Bay Area's physical and social environment. This analysis, it is hoped, will be useful in the making of future decisions in transportation-planning, urban development and environmental management.

The Environment Project was scheduled in two parts. Phase I, completed in July 1975, considered BART's direct effects on its environment. Phase II, now in progress, will emphasize the response of Bay Area residents to those effects. It is scheduled for completion in July 1977.

The Phase I study was conducted for MTC by Gruen Associates, Inc. and De Leuw, Cather & Co. The research was supported by the U.S. Department of Transportation and the U.S. Department of Housing and Urban Development.

This report summarizes the findings of Phase I. It is intended for public officials and other readers who have a general interest in transportation systems and their effects. More detailed information appears in the reports listed in Section 8.

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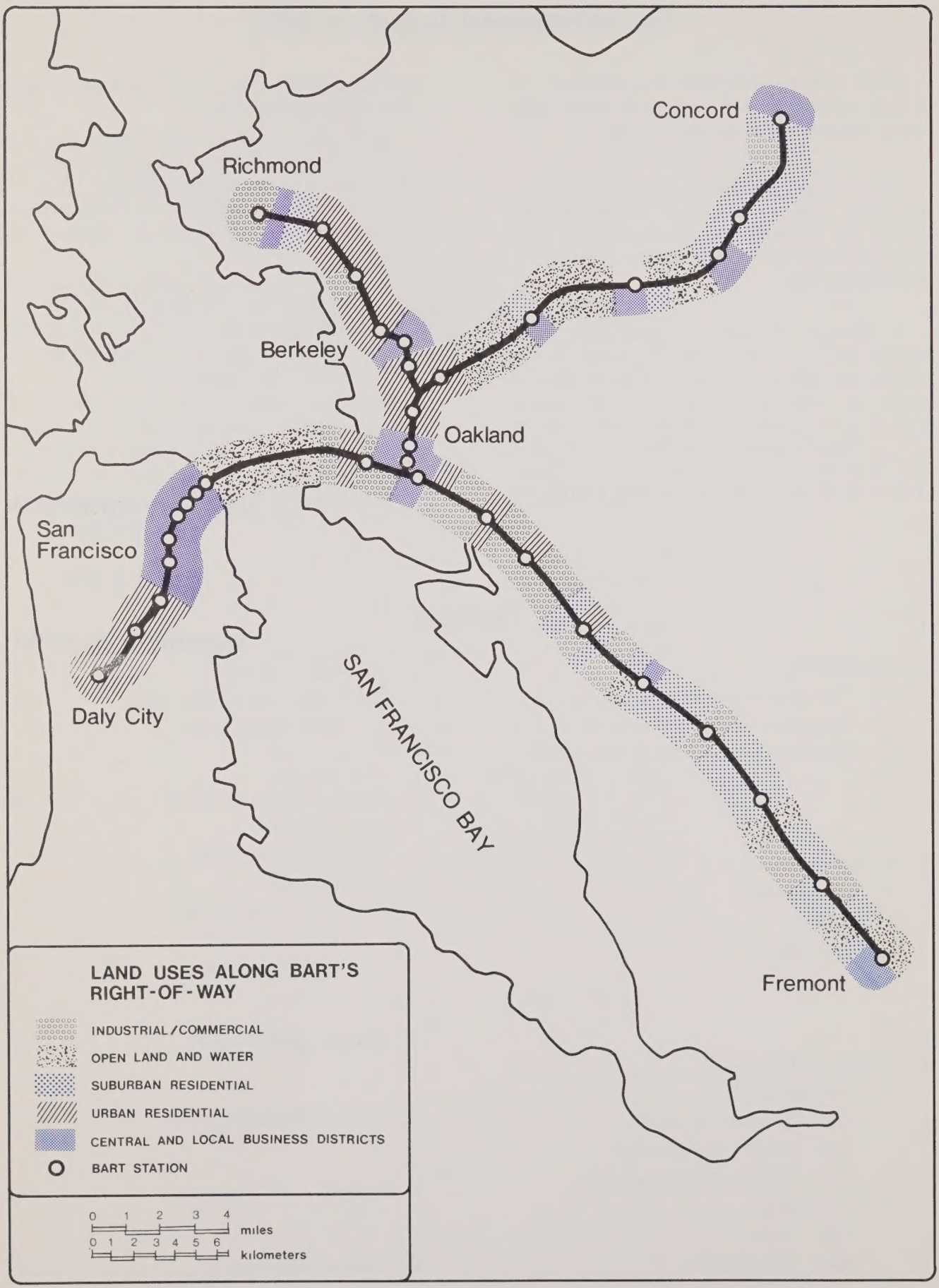
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1 The BART System

1.1 Size, Cost and Components

BART lies within three Bay Area counties — San Francisco, Alameda and Contra Costa — whose combined population was shown as 2.4 million in the 1970 census. The system traverses 14 municipalities and several unincorporated areas. More than 1 million people live within one mile of BART trackways.

BART's four lines radiate from the dense urban cores of San Francisco and Oakland, and are named for their termini: Richmond, Concord, Fremont and Daly City. All of the lines pass through older, medium density residential and industrial areas; the Concord and Fremont lines extend into newer, low-density suburbs.

The capital cost of building and outfitting BART was about $1.6 billion. This was raised chiefly through bonds. Funds for servicing the bonds came from bridge tolls, a property tax and a sales tax collected in the three BART counties.

The combined length of BART rights-of-way is 71 miles. Of this, about 20 miles are underground: 13 miles in subway tunnel built by boring or by cut-and-cover operations; 3 miles in a hard-rock tunnel on the Concord line; and 4 miles in the Transbay Tube beneath San Francisco Bay. The remaining 51 miles of BART trackways are at grade, or on earth embankments, or an aerial structures.

About 85% of BART's trackways lie within, beside or below the rights-of-way of other transportation routes, such as arterial streets, highways and railroads.

BART has 34 stations, of which 14 are below ground. Parking lots are included in 23 of the stations. Their capacity ranges from 240 to 1,400 cars. Combined capacity of the 23 lots is 18,000 cars.

Opposite page: Land-use patterns along BART'S rights-of-way. Most of BART lies in areas that were urbanized before BART was built. This is one reason why BART has had little effect on the natural environment.

1.2 Train Operations

BART cars are 70 feet long; each can carry 72 seated passengers. Train length varies between 2 and 10 cars. Maximum operating speed is 80 miles an hour.

During the Phase I study, BART trains operated on weekdays only, between 6:00 AM and 8:00 PM. Headway — the time between successive trains — was 6 minutes on the Fremont and Daly City lines, and 12 minutes on the Concord and Richmond lines.

BART inaugurated limited nighttime service late in 1975. Service expansions now planned would reduce headways through the Transbay Tube to 2 minutes during peak hours; add more trains to the nighttime schedule; and provide BART's first weekend service.

1.3 Special Properties

BART is a specialized system whose major purpose is to carry commuters between a dense urban focus and numerous outlying communities. This purpose is reflected in both its design and its patronage. BART's tracks and stations are spead over a broad area; distances between its suburban stations range from two to four miles. About 70% of the patrons who use BART are traveling between their homes and their jobs. The average length of a trip on BART is 13 miles.

BART differs strikingly, then, from the older transit networks that serve the concentrated populations of New York, Boston and some European cities. This must be remembered when BART's lessons are used in evaluating rapid-transit alternatives elsewhere.

2 The Phase I Study

2.1 Major Features

The research described in this report was not a conventional environmental-impact study, because the Environment Project has several unusual characteristics.

The Project is analyzing the actual effects of an existing system — not the predicted effects of a proposed system.

"Environment" is broadly defined. It embraces not only the common environmental parameters — such as air quality and noise levels — but also some aesthetic, psychological and social factors that usually are not considered in environmental-impact research.

The research plan accommodates feedback. Some unanticipated effects found in Phase I will be explored in Phase II. And hypotheses about people's responses to BART, to be tested in Phase II, are based on the findings of Phase I.

2.2 Methods

The Phase I study employed a broad variety of research methods. These included direct observation, interviews with local officials and BART personnel, analysis of published and unpublished statistics and reports, instrumental measurements and modeling. In some cases, new methods were devised specifically for this research, although methods-development was not a major objective of the study.

2.3 Limitations

Some limitations of the Phase I study must be emphasized:

- It did not evaluate the environmental impact of BART's construction.

There is evidence that construction operations — especially those associated with BART stations — generated substantial environmental effects. But the surviving records of those effects are too fragmentary to make possible a reliable analysis.

- It depicts transient conditions: some of BART's environmental effects will change as BART operations are expanded.
- It presents only preliminary information about how residents of the Bay Area perceive BART's effects and respond to them.

These perceptions and responses — like the effects themselves — can be expected to change with time. Many residents will become more accustomed to BART; and some of the persons most sensitive to BART's effects will escape them by moving away. Research into these phenomena has been allocated to Phase II of the Environment Project.

3 Findings: BART's Impact

3.1 Regional Effects

BART's effects on the Bay Area environment can be divided into two categories: regional and local.

On the regional scale, only two effects have been identified: BART has produced a small reduction in the emission of air-pollutants from automobiles; and it has given new visual emphasis to existing urban centers and regional transportation corridors.

BART has worked no significant effects on the natural environment.

3.11 Effects on air quality BART's net effect on regional air quality has been a small reduction in pollution. Even if BART operations are expanded to provide all of the service now planned, the total reduction in automobile-miles travelled in the three BART counties will be about 3%. Automotive emissions in BART's entire service area will decline by a similar percentage.

It is noteworthy that a survey of public attitudes toward BART, made in 1972, showed that many residents of the BART counties thought that the system would engender a substantial reduction in automobile travel, and a correspondingly substantial improvement in air quality.

BART is not a pollution-free mode of transportation. It consumes electrical energy, and the power plants that produce that energy also produce pollutants. But the incremental pollution attributable to the generation of electricity for BART is negligible, when compared with the BART-induced reduction in emissions from cars.

3.12 Effects on urbanization BART is a radial system, focused on downtown San Francisco, Oakland and Berkeley. It has reinforced existing centers of population and activity visually and functionally, by locating its major stations in these downtown areas, and by inducing municipal improvement projects that were coordinated with BART's construction.

These improvements included the development of plazas and pedestrian malls, and the refurbishing of major urban streets. They must be counted among BART's most important positive effects on its environment. The redevelopment of Market Street in San Francisco is a noteworthy example; others can be found in Berkeley and Oakland.

In a few outlying areas, BART structures have created new centers of visual focus in urban or suburban settings. And BART trackways, following the rights-of-way of railroads and highways, have given significant visual reinforcement to regional transportation corridors.

Limited evidence suggests that BART has linked outlying communities more strongly to its urban center, by making residents of the BART counties more aware of the existence and positions of these peripheral population centers. This hypothesis was not investigated formally during the Phase I study. It will be tested during Phase II.

3.13 Impact on natural environment BART's effects on components of the natural environment — soils and geology, drainage and water systems, and living things — were assessed through field observations, literature searches for sensitive natural structures and biological communites along BART's routes, discussions with university sources, and interviews with local officials and BART personnel who had observed BART's construction.

The building and operation of BART have worked no significant effects on the environmental components considered. There are two major reasons for this:

- BART's designers sought to minimize such effects.

Example: In designing and locating BART parking lots, they made certain that runoff from the lots would not tax the capacity of local storm drains. In some cases, BART paid for the enlargement of municipal drainage channels to accommodate additional waste-water from a BART station itself and from private development that might be attracted into the neighborhood by the station.

- Most of BART lies in areas that already were urbanized when the system was built. The few non-urbanized places traversed by BART were not ecologically unique or sensitive.

3.2 Local Effects

BART's most important local effects are the noise of BART trains and the visual impact of its structures.

3.21 Noise Noise was measured by instruments aboard BART trains and near BART trackways. In general, BART trains generate about as much noise as the buses or automobiles that would be needed to move as many passengers past a given point.

A BART train in Oakland. The combined length of BART rights-of-way is about 71 miles. About 85% of BART's tracks follow railroads, highways or streets.

Along some portions of BART's aerial trackways — especially in residential neighborhoods — the sound of BART trains exceeds ambient sound levels. This effect falls chiefly on dwellings that stand within 250 feet of a track centerline, and that are not shielded from the trackway by natural or man-made barriers.

BART's noise is greatest at switches, tunnel openings and overpasses. BART includes 15 tunnel openings, 25 overpasses and more than 90 switching points — many of them in residential neighborhoods.

The finding that BART generates substantial acoustic effects has special importance. When public expectations about BART were surveyed in 1972, few of the respondents in selected areas near BART trackways thought that BART would produce significant noise.

BART's acoustic impact is worsened — especially in residential neighborhoods — by the noise of nighttime maintenance work.

Further measurements of the noise from BART trains will be made during Phase II, to learn how the age and condition of BART cars affect their noisiness.

Inevitably, BART's acoustic impact will be noticed more as nighttime service increases; noise probably will become BART's most important effect on residential neighborhoods. (This prediction is discussed in Section 6.)

3.22 Visual effects The visual effects of the BART system were considered both quantitatively and qualitatively. The visual impact of a BART structure is determined chiefly by its scale, its mass, its architectural detail, its attendant landscaping and the changes that the structure induces in open spaces, pedestrian areas and thoroughfares. This visual impact was evaluated by judging the extent of contrast between each structure and its environment. Then criteria adapted from the San Francisco Urban Design Plan* were used in judging whether the impact was favorable or adverse. This assessment of BART's visual impact, by the methods outlined above, showed that:

- Along approximately half of its length, BART has produced little or no visual impact.

This visual neutrality arises chiefly from: the location of almost one-third of the system underground; the placement of aboveground trackways along the routes of existing roads and railroads; the construction of many BART stations near existing, large structures, such as shopping centers; and the decision to build about one-third of BART'S stations without parking lots.

- Along a quarter of its length, BART has created adverse visual effects — especially in residential areas.

These effects arise from obtrusive aerial trackways; from highways that have been widened to accommodate BART tracks; from neglected vacant land near the BART right-of-way in Berkeley; and from conspicuous stations in residential areas. Almost all of BART's parking lots in residential neighborhoods clash visually with their surroundings. Further information about the visual characteristics and visual impact of BART stations appears in Section 4.

- Along the remainder of its length, BART has created positive visual effects, directly or indirectly.

Direct visual improvements arose from the screening of unattractive features by BART structures, from the development of linear parks under aerial trackways, and from BART's easing the transition between different modes of land-use — e.g., residential and industrial.

Indirect visual enhancement arose from municipal improvement projects induced by BART *(see Part 3.12)*.

3.23 Vibration The vibration produced in nearby structures by BART trains on aerial trackways and in subway tunnels was measured directly by instruments. In general, such vibration seems comparable to the vibration caused by passing trucks. But measurements of vibration during Phase I were not extensive, and further research is being conducted during the Phase II study.

3.24 Effects on air quality BART's impact on local air quality was evaluated through direct measurements of carbon monoxide near BART stations. Traffic at these stations produces a small increase in local pollution. In general, however, air quality near stations is not notably different from the quality that would prevail if BART had not been built.

3.25 Social impact The Phase I study considered four social parameters that could have been affected by BART: traffic barriers, safety, crime and privacy. In general, BART's local social effects have been small.

Barriers: BART has created few barriers to ped-

*San Francisco Department of City Planning. 1971. *The Comprehensive Plan. Urban Design.*

A suburban station on BART's Fremont line. The system's greatest effects on local environments are its noise and the visual impact of BART structures.

estrians or vehicles; in some places, BART has improved the flow of both. This was ascertained by inspecting maps and aerial photographs to find old routes that had been blocked by BART, and new routes that had been created or improved during BART's construction.

These new routes included pedestrian bridges across BART rights-of-way, and widened vehicular underpasses beneath routes shared by BART and an adjacent railroad.

Safety: BART's only effect on safety beyond the boundaries of BART facilities is related to automobile traffic. Cars moving to and from some heavily used stations have caused local congestion and an attendant increase in the frequency of accidents.

Crime: BART-related crime has been limited to thefts of bicycles, thefts of automobiles and thefts from automobiles in parking lots and on nearby streets. BART installations have not fostered an increase in crimes against persons.

Crime within the system — i.e., on BART trains and in stations — is being studied during Phase II. Preliminary findings indicate that such crime is not an important problem. It consists almost wholly of petty thefts, vandalism and fare-evasion, averaging about five such incidents a day in the entire system.

Privacy: Along approximately 15 miles of its trackways, BART has exposed to public view areas that formerly were private — for example, back yards of dwellings. But very few of the persons thus affected have erected screens or other devices to restore their privacy. Whether residents near BART tracks have changed the ways in which they use yards or rooms facing the tracks is not known. This will be investigated during the Phase II study.

Very few commercial organizations have directed signs or other displays toward BART trackways.

4 Findings: Sources of Impact

BART's most important environmental effects arise from aerial trackways and from BART stations — especially the stations that include parking lots.

4.1 Trackways

In residential areas, aerial tracks on narrow rights-of-way have produced significant adverse effects. These are due to the noisiness of elevated trackways; the location of tracks close to existing buildings; the exposure of previously private areas to observation from BART trains; and the creation of undesirable shadows.

In general, these effects are worse than the effects that might be expected from tracks on embankments and on wider rights-of-way. This is especially true of noise. The very structure of aerial trackways makes them noisier than embankments and the noise originates at a level higher than most common barriers, such as fences, walls and shrubbery.

The adverse visual effects of aerial tracks in residential neighborhoods is offset partially by the beneficial impact of linear parks. A noteworthy example is the extensively landscaped park, 2.7 miles long, beneath the BART trackway in the El Cerrito-Albany area.

In most places, the location of BART tracks along the routes of existing highways, railroads and arterial roads was environmentally advantageous: it mitigated BART's adverse effects. If the existing route was reasonably distant from dwellings and other structures, and if it already was heavily used, the effects of adding BART tracks to the right-of-way were modest.

In a few cases, however, these conditions did not apply. An example occurs in El Cerrito, where a BART line follows a railroad right-of-way. Under normal circumstances, the railroad handles only two trains each day, and is scarcely noticeable to local residents. The impact of the BART line that now shares this right-of-way is almost as great as it would have been if there had been no pre-existing transportation route there.

In places where BART trackway was combined with an existing highway, the highway often masked BART's direct acoustic and visual effects. But where a highway through open space or through a suburban area had to be widened substantially to accommodate BART, the resulting broad right-of-way created strong, adverse visual effects.

BART lines in subway tunnels seemed to produce no important negative environmental impact, excepting the disruption that accompanied construction.

4.2 Automobile Traffic

Wherever there are BART stations with parking lots, the resulting traffic may cause congestion, increased frequency of accidents and increased local air pollution.

4.3 Stations

BART stations are major sources and foci of environmental impact. Almost all of the stations that include parking lots have engendered adverse local effects: residential and commercial dislocation during construction of the lots; visual disharmony; thefts from BART parking lots; local traffic congestion; heavy overflow parking on nearby streets; and often, offensively bright lighting of the parking lot at night.

4.31 Visual aspects In non-residential districts, BART stations usually are consonant with their surroundings.

In residential neighborhoods, stations often create a strong, adverse visual impact. Station structures contrast sharply with adjacent houses, in both scale and design. And their large, barren parking lots clash with the tree-lined streets surrounding them.

Generally, the least obtrusive stations in residential areas have these characteristics: They were deliberately designed and located to be inconspicuous. They are relatively small. They use adjacent back yard fences (rather than streets) as parking lot boundaries. They are served by several small parking lots, rather than a single large lot. And they make extensive use of landscaping.

Landscaping can reduce significantly the adverse visual impact of parking lots (and of high trackway embankments, too).

Although the use of landscaping at BART stations was limited, enough examples exist to demonstrate its efficacy. Extensive use of trees — especially, of existing mature trees — was very helpful in integrating large parking lots into residential areas.

4.32 Illumination The nighttime glare from parking lot illumination has been a minor problem at some BART stations. Most of the lots use unshaded, high-intensity lights, and most have more of these lights than are necessary.

The latter fact was demonstrated conclusively during a recent attempt to save electrical energy. About half of the lights at most parking lots were removed from service. The level of illumination in the lots remained adequate nonetheless, and there is no evident need to resume using these lights.

At the one BART station whose parking lot has shaded lights, the effectiveness of the shades in reducing lateral glare can be seen readily.

4.33 Traffic flow The design of parking lots, and the movement of motor vehicles between BART stations and adjacent streets, sometimes create conflicts between pedestrian and vehicular traffic.

All of BART's parking lots allow patrons to arrive and depart by bus or by automobile. At some stations, a potentially dangerous traffic pattern exists: buses, patrons walking in from the parking lot, and automobiles delivering patrons all converge on the same entrance points. This problem occasionally is compounded by dangerous exits from the parking lot to city streets.

It is significant that careful design avoided these problems at several stations.

Traffic controls at stations — both inside and outside parking lots — can affect safety significantly. BART parking lots were equipped initially with nonstandard and incomplete traffic signs that confused drivers. This condition is being corrected now, through the revision of existing signs and the addition of new ones.

Strategies for controlling BART-related traffic on streets near BART stations varied greatly among local jurisdictions. Some jurisdictions planned traffic-control before a station was built; some acted only after the station was operating; some did nothing at all. Where important traffic-control problems exist on city streets, it appears that they could have been avoided by planning and cooperation between the rapid-transit agency and the local government.

A BART elevated trackway in Oakland. In general, the environmental effects of aerial tracks are worse than those of tracks at grade or on embankments.

An aerial trackway through a commercial district in Oakland. The Phase I study showed that most of BART's effects occur fairly close to its trackways.

5 Findings: Sites of Impact

Most of BART's environmental effects are limited to strips of land, a few hundred feet wide, along BART trackways. About 0.5% of the population of the BART counties lives within these strips. This estimate is based on a survey of census blocks, using the 1970 census.

Most of the environmental effects at stations do not extend far beyond the station boundaries. Even the effects of stations in residential neighborhoods are restricted to the blocks immediately adjacent to the stations.

Glare from parking lot lights, the visual impact of stations, and the noise from BART trains and BART-related automobile traffic generally are confined to the first row of buildings around the station.

Stations at line terminals have unusually strong environmental effects. The terminal station on the Daly City line is used more heavily than was anticipated, with adverse effects on local safety and traffic flow, and on the availability of parking spaces at the station and on nearby streets. Lesser but similar problems occur at Fremont and Concord, and might arise at Richmond when direct service across the Bay begins on the Richmond line.

Most of BART's environmental impact is borne by middle-income and upper-middle-income persons living near suburban stations and above-ground lines. There is no evidence that poor people, old people or members of any ethnic minority bear an inordinate share of BART's adverse effects.

6 Effects of Expanding Service

At present levels of service, the environmental effects of BART operation (as distinguished from BART facilities) are small. The findings of the Phase I study have been used in forecasting the effects of planned expansions of service.

There is no evidence that increases in service will create any favorable environmental effects, or mitigate any existing adverse effects. Service expansion will have no significant impact on regional or local air quality.

In general, the adverse impact of above-ground trackways and parking lots will be amplified — especially along the Fremont and Concord lines. These lines attract more patrons than do the other two lines, and will continue to do so; and proportionally more of their tracks are above-ground.

Acoustic impact will increase in severity and extent, over large segments of the system. When nighttime service begins, the associated noise probably will become BART's most important effect on residential neighborhoods. The nighttime ambient sound level in such neighborhoods is demonstrably low. BART noise could disturb residents in the one or two blocks adjoining most of the above-ground tracks through residential areas.

7 Analysis

This section restates briefly some of the important findings of the Phase I study, and discusses their implications for the planning of other urban transit systems.

There is evidence that the construction of BART created major environmental effects (reported in Section 2, Part 2.3).

Although the impact of construction was not studied formally, anecdotal information suggests that this impact was severe in many instances. This information comes from newspaper articles, from complaints received by BART officials, and from an opinion survey made in 1972 by researchers at the University of California.

In general, the construction of BART tracks on highway medians and on embankments traversing undeveloped areas produced very little environmental impact.

Construction of station parking lots and elevated trackways created some significant effects, including noise and the disruption of traffic. These were most noticeable at station sites in residential neighborhoods.

Construction of BART's underground sections generated noise, barriers to pedestrian and vehicular traffic, accident hazards, airborne dirt, and local visual degradation. In some cases these effects lasted for several years, and seem to have made strong impressions on local populations — especially in downtown areas, which generally lacked the flexibility to adjust to a major construction project.

Planners can use several tactics for minimizing the disruptions caused by the construction of subways:

They should create a central authority for scheduling all work, and should keep the affected population informed of work plans. They should provide alternative means of transportation through areas where subway construction has impeded traffic. And they should establish a system for responding rapidly and effectively to complaints from affected residents. These complaints may embrace a wide variety of provocations, including noise, the severing of underground utility mains, and real or imagined danger to historically significant buildings.

At the regional level, BART's impact has been slight. (Part 3.1).

This statement carries major significance. BART is an unusually long, spread-out system. And although its tracks through urban centers lie in subway tunnels, most of the system is above-ground. The construction of BART was a major project — economically and technologically — that bore great potential for environmental effects. The Phase I study showed, however, that BART has been integrated into the Bay Area with minimal environmental disruption.

A general appraisal of BART's environmental effects can profit by a comparison of this rapid-transit railroad with two alternative modes of transportation that might have been chosen instead: new highways for automobiles, or express buses to operate on existing highways and city streets.

When it is compared with a highway (and the

automobiles that the highway implies), BART seems to produce modest environmental effects. A railway can use a relatively narrow right-of-way, and its construction entails less environmental disruption than does the building of a major highway. Tracks and stations can be placed underground in population centers. Fewer trains than automobiles are required to carry a given number of passengers past a given point, so the trains create less visual impact. And trains generate much less air pollution.

But when it is compared with a fleet of express buses carrying the same number of travelers, BART seems to generate a strong overall impact. Its elevated trackways are substantial and permanent sources of visual effect — usually negative. So are the parking lots at most BART stations. And the installation of a fleet of buses entails no environmental disruption comparable to the construction of BART.

On the other hand: Wherever a rail system can be placed underground, its impact becomes negligible as soon as construction is finished. Buses become continual sources of noise and air-pollutants.

BART's effect on regional air quality has been small (Part 3.1).

This finding must be interpreted and used with caution. A transit system's impact on air quality will depend greatly on the system's absolute size and its ability to divert patrons from automobiles. Transit systems in other urban areas might differ sharply from BART in both respects.

The impact of a rapid-transit railway on regional air quality also will be affected by the methods that its patrons use in traveling to and from its stations. To attract maximal patronage, the system should provide abundant parking for automobiles at its suburban stations. But the quantity of pollutants generated by an automobile traveling to a station may be a substantial fraction of the total pollution that would be created if the entire trip were made by automobile.

If pollutant emissions alone are considered, local buses provide the best way for patrons to reach rapid-transit stations. But local bus systems are costly, and many travelers will not use them.

BART's impact on the natural environment has been negligible (Part 3.1.).

This is attributable largely to special properties of the Bay Area and of BART itself, as summarized in Parts 1.1, 1.3 and 3.1. In other regions, a rapid-transit system might have much greater impact. Example: the stream-valley parks near Washington, D.C., would be far more sensitive to such a system than are the grassy open spaces traversed by BART.

Track discontinuities are major sources of noise (Part 3.2).

Careful location of features such as switches — especially, placing them away from residences — can reduce their acoustic impact significantly. So can the use of sound barriers and wider rights-of-way, where technical and economic constraints do not make them impractical.

Aerial trackways create exceptionally strong acoustic and visual effects (Part 4.1).

The typical rapid-transit rail system will have some elevated track sections. The design and location of these sections will affect the cost of the system, the service that it provides to its patrons, and its environmental impact.

Patrons will find the system most useful if its lines pass close to residential and commercial centers. But the location of elevated trackways near such centers will create inordinately strong visual and acoustic effects.

In residential neighborhoods or other quiet areas, designers should consider: alternative routes for aerial lines; the avoidance of narrow rights-of-way; the construction of sound barriers; and the use of tracks on embankments or in subway tunnels, rather than on aerial structures. All of these tactics can increase the system's cost. In the case of subway tunnels, the impact on cost can be very large.

It is noteworthy that the residents of Berkeley chose to have BART tracks there placed underground; BART's original plans called for aerial trackways in Berkeley. The suppression of noise seems to have been one reason why the Berkeley voters favored subway tunnels, even though they had to pay for their choice through higher local taxes.

Linear parks can offset, partly, the adverse impact of aerial tracks (Part 4.1.).

The use of linear parks in a few places was an important experimental element in BART's design. Their favorable impact seems to have been demonstrated convincingly. They should be considered in the design of other systems, for diluting the impact of aerial trackways on residential areas.

Combining BART tracks with other transportation structures was usually advantageous (Part 4.1).

In most places, the use of combined rights-of-way reduced BART's adverse acoustic and visual effects. In a few cases, however, this was not true. Designers should recognize that the physical form, location and use of an existing right-of-way determine whether it can accommodate a rapid-transit line advantageously.

BART-related automobile traffic is a problem in some suburban communities (Part 4.2).

A decision to encourage patrons to use automobiles for access to rapid-transit stations must be made with care. The reliance of BART patrons on automobiles has worked adverse effects on the patrons themselves, and on local areas served by BART stations.

Stations with parking lots create BART's most important and direct environmental effects (Part 4.3).

The design and placement of stations entails some important trade-offs. Stations should be close to the patrons that they serve, but the station parking lots create visual intrusions — both by day and by night — in residential neighborhoods. And the flow of buses and automobiles to and from the stations is detrimental to such neighborhoods.

The negative effects of BART's stations with parking lots might have been mitigated greatly, or even eliminated, if such stations had been excluded from residential neighborhoods; or if BART's planners had decided to provide fewer parking lots. Either choice would have required corresponding improvements in feeder-bus service to the stations.

In residential neighborhoods, BART stations often create strong, adverse visual effects (Part 4.3).

This finding might be exploited in the development of design guidelines for other tansit systems serving residential communities. The guidelines would emphasize the factors listed in Item 4.31.

The effects of stations do not extend far beyond the station boundaries (Section 5).

This finding suggests that stations — even those with parking lots — can be placed near residential neighborhoods and other sensitive areas, if design and location are chosen with due care. Dwellings directly adjacent to the stations will experience significant impact in any case.

Stations at line terminals produce unusually severe effects (Section 5).

Particular care must be exercised in the placement and planning of terminal stations, which bear an inordinately large share of parking and patronage.

Planned expansion of service will exacerbate BART's acoustic impact (Section 6).

The acoustic impact of a system like BART can be sensitive to operating schedules. Acoustic effects must be considered during the planning of systems that will use short headways, or that will operate trains at night through residential areas.

Expansion of service will aggravate problems associated with stations (Section 6).

This suggests that there are practical limits on station size. At some of BART's suburban stations, those limits already may have been reached.

If a transit system is to harmonize with an environment like BART's, a decision favoring smaller, more numerous stations would merit examination. Obviously, such a decision would not be based on environmental-impact forecasts alone; it would be influenced strongly by consideration of capital cost, operating cost, average operating speed and energy-consumption, among other factors.

8 Technical Literature

These MTC publications will provide further information about Phase I of the BART Impact Program's Environment Project. All of them will be available from the National Technical Information Service (Springfield, Va.).

Impacts of BART on the Natural Environment: Interim Service Findings. 1976.
Report No. TM 17-4-76 79 pp. + appendix.

Environmental Impacts of BART: Interim Service Findings. 1976. In press.

Impacts of BART on Air Quality: Interim Service Findings. 1976. In press.

Impacts of BART on Visual Quality: Interim Service Findings. 1976. In press.

Impacts of BART on the Social Environment: Interim Service Findings. 1976. In press.

Acoustic Impacts of BART: Interim Service Findings. 1976. In press.